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SURVEY OF RELATIVE HARDNESS OF SELECTED IMPACT AREAS, YUMA PROV--ETC(U)
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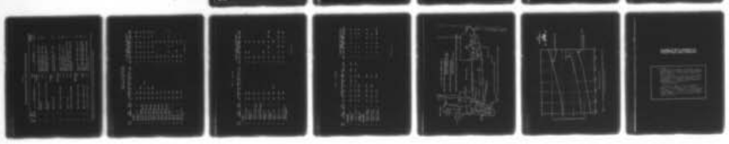

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MISCELLANEOUS PAPER M-77-10

SURVEY OF RELATIVE HARDNESS OF SELECTED IMPACT AREAS YUMA PROVING GROUND, ARIZONA

by

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Final Report

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Prepared for U. S. Army Materiel Development and Readiness Command, Project Manager for Selected Ammunitions, Picatinny Arsenal
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Yuma Proving Ground was visited to conduct a survey of the relative hardness of selected impact areas to establish the most suitable sites for a survivability test as part of DT II testing of 155mm XM718/741 Remote Anti-Armor Mine System (RAAMS).

Soil/terrain data were collected at Z, R, Cain, and Adam Fields located along the north side of Poleline Road. Z and R Fields were located on nearly level,

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20. Abstract (continued)

moderately dissected gravelly piedmont which had recently been graded and compacted to achieve a high strength within the compacted layer. Cain Field is located on a wash. The area is undulating and bare. Adam Field is located on predominantly gravelly undissected piedmont with some wash areas. The area is undulating and the brush vegetation was removed.

The surface materials at the four impact areas visited are predominantly coarse-grained soils with some areas having large amounts of gravel and caliche. The soil was slightly moist and firm when sampled. The cone index ranged from 300 to 500 in the 0- to 6-in. layer, and the dynamic cone penetrometer blows per foot for the surface 12 in. ranged from 17 to 34.

A comparison of calculated peak rigid body deceleration-impact velocity relation for selected surface materials revealed that the magnitude of the rigid body g forces that the RAAM can experience upon impact with various earth materials varies considerably. The estimated peak deceleration of RAAM at R and Z Fields ranges from about 4,000 to 16,000 g's at impact velocities of 100 and 400 ft/sec, respectively. In frozen soil, the peak decelerations are approximately 13,000 g's at 100 ft/sec and 25,000 g's at 400 ft/sec. For soft rock, the deceleration values are about 30,000 g's at 100 ft/sec, and 43,000 g's at 400 ft/sec. At a velocity of 100 ft/sec, the magnitude of peak deceleration on frozen ground and soft rock is about 3 and 7.5 times that at R and Z Fields, respectively.

On the basis of the evaluation of YPG impact areas, R and Z Fields are the most suitable sites for conducting RAAM survivability tests.

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Preface

This study was conducted during the period 30 November - 3 December 1976 by personnel of the U. S. Army Engineer Waterways Experiment station (WES) for the U. S. Army Yuma Proving Ground (YPG), in conjunction with the U. S. Army Materiel Development and Readiness Command (DARCOM), Project Manager for Selected Ammunitions, Picatinny Arsenal, Dover, New Jersey. Authority for the study is contained in a teletype from the Commander, YPG, dated 9 November 1976 as part of DT II Testing of 155mm XM718/741 Remote Anti-Armor Mine System (RAAMS).

The study was conducted under the general supervision of Messrs. W. G. Shockley, Chief, Mobility and Environmental Systems Laboratory (MESL), and J. P. Sale, Chief, Soils and Pavements Laboratory (SPL). Field support activities at YPG were accomplished under the direction of Mr. Graham Stullenbarger. The report was prepared by Mr. A. A. Rula, Chief, Mobility Systems Division, MESL, and Dr. B. Rohani, Research Group, Soil Dynamics Division, SPL.

COL J. L. Cannon, CE, was Director of WES during the conduct of the study and preparation of the report. Mr. F. R. Brown was Technical Director.

Contents

Conversion Factors, U. S. Customary to Metric (SI) Units of Measurement

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	0.0254	metres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
feet per second	0.3048	metres per second

SURVEY OF RELATIVE HARDNESS OF SELECTED IMPACT AREAS

YUMA PROVING GROUND, ARIZONA

1. At the request of Picatinny Arsenal (PA), Mr. A. A. Rula and Dr. B. Rohani visited Yuma Proving Ground (YPG) during 30 November-3 December 1976 to conduct a survey of the relative hardness of selected impact areas to establish the most suitable site for a survivability test as part of DT II testing of XM718/741 remote anti-armor mine systems (RAAMS), U. S. Army Test and Evaluation Command (TECOM) Project No. 2MU-003-718-004. Authority for the visit is given in TWX from Commander, YPG, dated 9 November 1976.

2. Upon arrival at YPG Messrs. Rula and Rohani met with Mr. Graham Stullenbarger, to make the necessary arrangements to visit the test areas. Five locations were available for testing: Z, R, Eve, Adam, and Cain Fields. After a discussion of the suitability of fields for testing, terrain characteristics to be expected, and soil hardness desired for the planned RAAMS tests, it was agreed that the fields would be surveyed in the following order: Z, R, Cain, and Adam Fields. Impact area Eve was excluded from further consideration because of its similarity (in terms of strength) to Adam Field.

Description of Areas Visited

3. A brief description of the areas visited by WES representatives is given in the following paragraphs. A map of the general location of the impact fields is given in Figure 1. Soil data are given in Table 1 and strength data in Table 2.

Z Field

4. This field is located on a moderately dissected gravelly piedmont about 10 miles* east along Poleline Road from the intersection of Firing Front Road and about one-half mile north of Poleline Road. The dimensions of the field are about 600 by 890 feet, and the long axis is oriented in a ENE-WSW direction. The area slopes about 1 percent in a southwesterly direction. The impact field has

* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

been recently graded and compacted using conventional equipment and compaction techniques necessary to achieve a high strength within the compacted layer.

5. Soil profile data were taken at Z Field at sites 3 and 6. Site 3 was located about 300 feet ENE of the center of the western boundary, and site 6 was located about 750 feet ENE of the center of the western boundary. The surface was covered with sand and gravel generally up to three-eighths inch. At site 3 the soil in the surface foot was a silty, gravelly sand (SM) with gravel predominating to one-half inch with some gravel larger than 1 inch. Caliche was also present in the soil material and acted as a natural binder. At site 6 it was very difficult to dig a hole beyond 6 inches with a D-handle shovel. In the surface 6 inches the material was classified as a clayey sandy gravel (GC) with some gravel up to 1 inch.

6. At the time of sampling the soil was moist and very firm. Soil strength data were taken at sites 3 and 6, and 10 other locations within Z Field. At each location three sets of cone penetrometer and two sets of dynamic cone drop penetrometer readings were made within a small area.* The capacity (750) of the cone penetrometer was exeeeded in most instances at the 1-inch depths. Penetration was somewhat easier with the dynamic cone penetrometer, but at five locations little penetration was achieved beyond 3 inches after 60 blows. Where penetration was possible in the surface foot, the blows per foot ranged between 72 and 126+.

R Field

7. R Field is located on a moderately dissected gravelly piedmont about 26 miles east along Growl Road (eastern extension of Poleline Road) from the intersection of Firing Front Road and about 1 mile north of Growl Road. The field is about 500 by 900 feet in size, with the long axis orientated in a ENE-WSW direction. The area slopes about 1 percent in a southeasterly direction. The impact area has been graded and compacted as has Z Field.

8. Soil profile samples taken at the center of the field (site 1) show that the surface layer consisted of small gravel up to three-eighths inch. Where difficulty was encountered in making cone penetrations, excavations at these points revealed that gravel greater than 1 inch was frequently encountered. It was estimated that the material contained about 30 percent gravel. Caliche was also present in the material.

*See reference 2 for sampling procedure.

9. At the time of sampling the soil was moist and very firm. Soil strength data taken at site 1 and 8 other locations at R Field show that the surface cone index was greater than 100 and the strength exceeded the capacity of the instrument at about the 1-inch depth. Penetration with the dynamic cone penetrometer was also difficult. Of the nine locations sampled, blows for the top foot could be determined at three sites and they ranged from 103 to 180+. In most instances, 60 blows would not penetrate the 3- to 6-inch or the 6- to 9-inch layers.

Cain Field

10. This field is located on a wash at the end of Water Recovery Road, which is about 6 miles NNW of the end of Growl Road. The field is about 3300 by 4200 feet, with the long axis oriented in a NE-SW direction. The area slopes less than about 1 percent in a southeast direction. Creosote bushes have been removed from the impact area. The area undulates gently in a NE-SW direction with about 1 to 2 feet of local relief. At the time of the visit about 50 percent of the surface was covered with gravel up to one-half inch.

11. Soil profile data taken at the center of the western boundary (site 1) indicate that the soil in the 0- to 6-inch layer was a sandy silt (ML) with a trace of gravel up to one-fourth inch, and that the soil in the 6- to 12-inch layer was a silty sand (SM) with a trace of gravel up to one-fourth inch. Near the center of Cain Field (site 2), the soil in the 0- to 12-inch layer was a very fine sandy silt with a trace of gravel up to one-half inch. At the center of the eastern boundary (site 3) the soil contained more gravel (about 20 percent). Soil profile data taken at this site show that the soil in the 0- to 12-inch layer was a sandy gravelly silt with gravel up to one-half inch.

12. At the time of sampling the soil was dry and fairly firm. Soil strength data taken at the same locations as the soil profile data show that the soil generally increased in strength with depth. The average cone index in the 0- to 12-inch depth exceeded 300, and the blows per foot obtained with the dynamic cone penetrometer averaged about 20 for the surface 12 inches.

Adam Field

13. Adam Field is located about 3.5 miles NNE of R Field on predominantly gravelly undissected piedmont with the low areas occupying washes. The field is about 3900 by 4200 feet with the long axis running in a ENE-WSW direction with the crests about 300 feet apart and relief in drainageways up to 10 feet. The slopes along the drainageways are

about 5 to 7 percent. The surface is a desert pavement consisting of gravel up to 1-1/2 inches. The surface also contains some boulders up to 12 inches. The impact area has been cleared of mesquite, ironwood, and paloverde trees and brush growth.

14. The soil was sampled for classification purposes near the center of the area on an upland flat (site 1), side slope (site 2), and in the bottom of an intermittent drainageway (site 3). At sites 1 and 2 the soil in the surface 12 inches was a silty sand (SM) with varying amounts of gravel up to about three-fourths inch. At site 3 the soil type was a silty sand (SM) with about 20 percent gravel up to one inch.

15. The soil was slightly moist and firm when sampled. The cone index ranged from 300 to 500 in the 0- to 6-inch layer, and the dynamic cone penetrometer blows per foot for the surface 12 inches ranged from 17 to 34.

Evaluation of Impact Areas

16. The soil data collected at the four impact areas visited at YPG indicate that the surface materials are predominantly coarse-grained with some areas having large amounts of gravel and caliche. In terms of type of surface materials, preparation of impact areas, and soil strength, R and Z Fields are similar and Adam and Cain Fields are similar. R and Z Fields are much firmer than the other two fields.

17. The most severe soil environment encountered in conducting survivability tests is hard frozen ground. However, because of the difficulties encountered in conducting a test program in cold environments, logistics, and cost, it is highly desirable to consider other areas as potential sites for conducting survivability tests.

18. A comparison of the dynamic cone penetrometer index (DCPI) data in reference 3 and in Table 2 indicates that R and Z Fields are not analogous to hard frozen soil. The most critical factor controlling the loading environment of the mine at impact is the strength of the target surface material to a depth of about 3 inches. The soil strength in the surface to 3-inch depth at R and Z Fields is quite low when compared to the surface strength of frozen soil. At R and Z Fields the number of blows required to penetrate the 0- to 3-inch layer varied from 5 to 15 with many readings in the 10 to 15 range. As reported in reference 3, for hard frozen soil the number of blows required to penetrate the 0- to 4-1/2-inch layer is often in excess of 150.

19. In order to provide guidance as to the magnitude of the deceleration forces that the mine would experience upon impact with surface materials

at the R and Z Fields, the penetration model documented in reference 4 was used to establish a relation (Figure 2) between peak rigid body deceleration and impact velocity. For these calculations an average cone index of 900 (extrapolated from 0- and 1-inch depth readings) and a density of 95 pounds per cubic foot were used to characterize the surface materials to a depth of 3 inches. Also included in Figure 2 are results of similar calculations for frozen sand and low strength rock targets which are documented in reference 5.

20. An examination of Figure 2 shows that the magnitude of the rigid body g forces that the RAAM can experience upon impact with various earth materials varies considerably. The estimated peak deceleration of RAAM at the R and Z impact areas ranges from about 4000 to 16,000 g's at impact velocities of 100 and 400 feet per second, respectively; at 200 feet per second the peak deceleration is about 7000 g's. In frozen soil the peak decelerations are approximately 13,000 g's at 100 feet per second, 15,000 g's at 200 feet per second, and 25,000 g's at 400 feet per second. For soft rock, the deceleration values are about 30,000 g's at 100 feet per second, 33,000 g's at 200 feet per second, and 43,000 g's at 400 feet per second. At a velocity of 200 feet per second, the magnitude of peak deceleration on frozen ground is about twice that at R and Z Fields. Peak deceleration in soft rock for the same impact velocity is about five times greater than that at R and Z Fields.

21. It should be noted that the deceleration of RAAM given in Figure 2 corresponds to rigid body deceleration. The duration of the peak deceleration is very short, probably less than 1 millisecond. Particle deceleration (or acceleration) due to stress wave propagation within RAAM is not considered in the evaluation.

22. On the basis of the evaluation of YPG impact areas, R and Z Fields are the most suitable sites for conducting RAAM survivability tests.

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Table 1

Soil Data for Selected Areas, Yuma Proving Ground, Arizona

Site No.	Test Date Dec 76	Site Location	Depth in.	Soil Type*	Moisture Content %
			Z Field		
3	3	300 ft ENE of center of western boundary	0- 6	Silty gravelly sand (SM) with gravel to 3/8 in.	6.1
			6-12	Silty gravelly sand (SM) with gravel to 1/2 in.	8.0
6	3	750 ft ENE of center of western boundary	0- 6	Clayey sandy gravel (GC) with some gravel up to 1 in.	--
			R Field		
1	1	Center of area	0- 6	Silty gravelly sand (SM) with gravel up to 3/8 in.	5.1
			Cain Field		
1	1	Center of western boundary	0- 6	Sandy silty (ML) with trace of gravel to 1/4 in.	6.7
			6-12	Silty sand (SM) with trace of gravel to 1/4 in.	7.0
2	1	Center of area	0-12	Very fine sandy silt with a trace of gravel up to 1/4 in.	—
3	1	Center of eastern boundary	0-12	Sandy gravely silt with gravel up to 1/2 in.	--
			Adam Field		
1	1	600 ft WSW of center of area	0- 6	Silty sand (SM) with gravel up to 3/4 in.	4.4
			6-12	Silty sand (SM) with small gravel	4.7
2	1	300 ft NE of center of area	0-12	Silty sand (SM) with gravel up to 3/4 in.	--
3	1	200 ft S of center of area	0-12	Silty sand (SM) with about 20 percent up to 1 in.	--

* Visual, classification in terms of Unified Soil Classification System (USCS).

Table 2. Soil Strength Data
Yuma Proving Ground, Arizona

Site No.	Site Location	Date Dec 76	Average Cone Index at Depth, In.							Average Dynamic Cone Penetration Blows per Layer						
			0	1	2	3	6	9	12	0-3	3-6	6-9	9-12	0-6	6-12	0-12
	Z-FIELD															
1	Center of W boundary	2	210	750+						10	30	38	48+	40	86+	126+
2	150 ft. ENE of center of W boundary	2	127	667+	750+					7	21	24	20	28	44	72
3	300 ft. ENE of center of W boundary	2	103	350	573	750+				5	22	40	47	27	87	114
4	450 ft. ENE of center of W boundary	2	190	600+	750+					9	28	29	22	37	51	88
5	600 ft. ENE of center of W boundary	2	123	493	750+					8	32	38	39	40	77	117
6	750 ft. ENE of center of W boundary	2	330	750+						14	60+			74+		
7	100 ft. WNW of center of E boundary	2	180	750+						10	60+			70+		
8	200 ft. WNW of center of E boundary	2	233	750+						15	60+			75+		
9	300 ft. WSW of ENE corner	2	290	750+						8	21	26	27	29	53	82
10	100 ft. S of Site 9	2	253	750+						8	60+			68+		
11	200 ft. S of Site 10	2	163	750+						14	46+	60+		60+		
12	300 ft. WSW of ESE corner	2	250	750+						15	60+			75+		

Table 2. Continued

Site No.	Site Location	Date Dec 76	Average Cone Index at Depth, In. 0	1	2	3	6	9	12	Average Dynamic Cone Penetration Blows per Layer 0-3	3-6	6-9	9-12	0-6	6-12	0-12
	R-FIELD															
1	Center of area	2	160	750+						7	16	60+		23		
2	Center of E boundary	2	217	750+						8	23	60+		31		
3	225 ft. W of center of E boundary	2	187	750+						12	60+			72+		
4	675 ft. W of center of E boundary	2	213	750+						13	60+			73+		
5	Center of W boundary	2	193	750+						8	48+	60+		56+		
6	Center of N boundary	2	287	750+						6	22	30	60+	28	90+	118+
7	100 ft. S of Site 6	2	263	700+	750+					8	60+			68+		
8	300 ft. S of Site 7	2	200	750+						10	48	62	60+	58	122+	180+
9	100 ft. S of Site 8 at center of S boundary	2	257	750+						12	34	33	24	46	57	103

Table 2. Continued

Site No.	Site Location	Date Dec 76	Average Cone Index at Depth, In. 0	3	6	9	12	0-6	6-12	0-12	Average Dynamic Cone Penetration Blows per Layer 0-3	3-6	6-9	9-12	0-6	6-12	0-12
	CAIN FIELD																
1	Center of W boundary	1	160	467	387	473	600+	338	500+	425+	3	6	6	8	9	14	23
2	Center of area	1	87	327	380	373	427	265	393	318	3	6	6	4	9	10	19
3	Center of E boundary	1	93	440	504+	613+		344+			2	5	6	7	7	13	20
	ADAM FIELD																
1	600 ft. WSW of center of area	1	137	703+	663+	750+		501+			4	8	9	13	12	21	34
2	300 ft. NE of center of area	1	140	413	450	639+		334			2	4	6	5	6	11	7
3	200 ft. S of center of area	1	143	547	750+			480+			3	10	16	32+	13	48+	61+

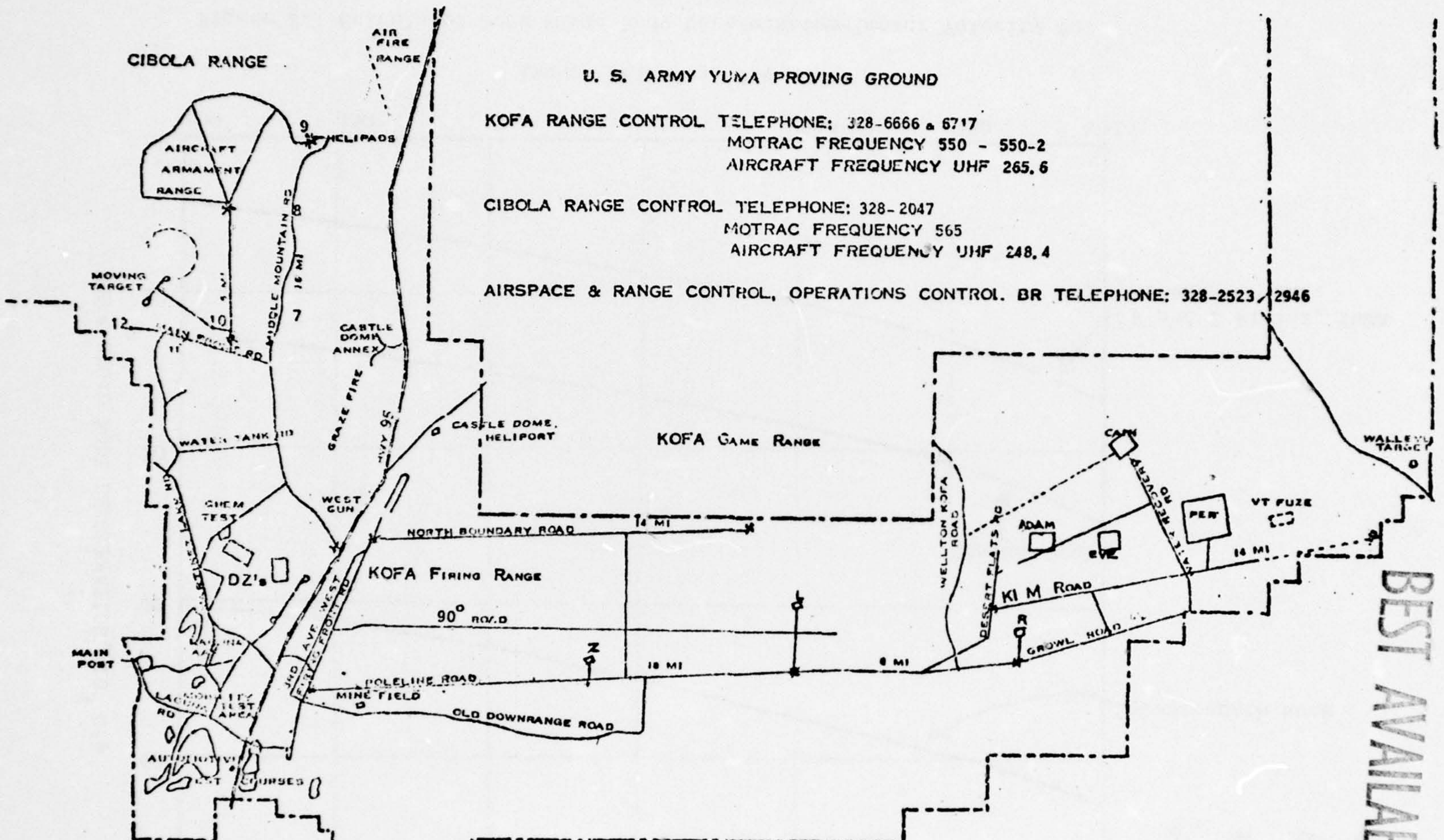

Figure 1. Location of Impact Fields, Yuma Proving Ground, Arizona

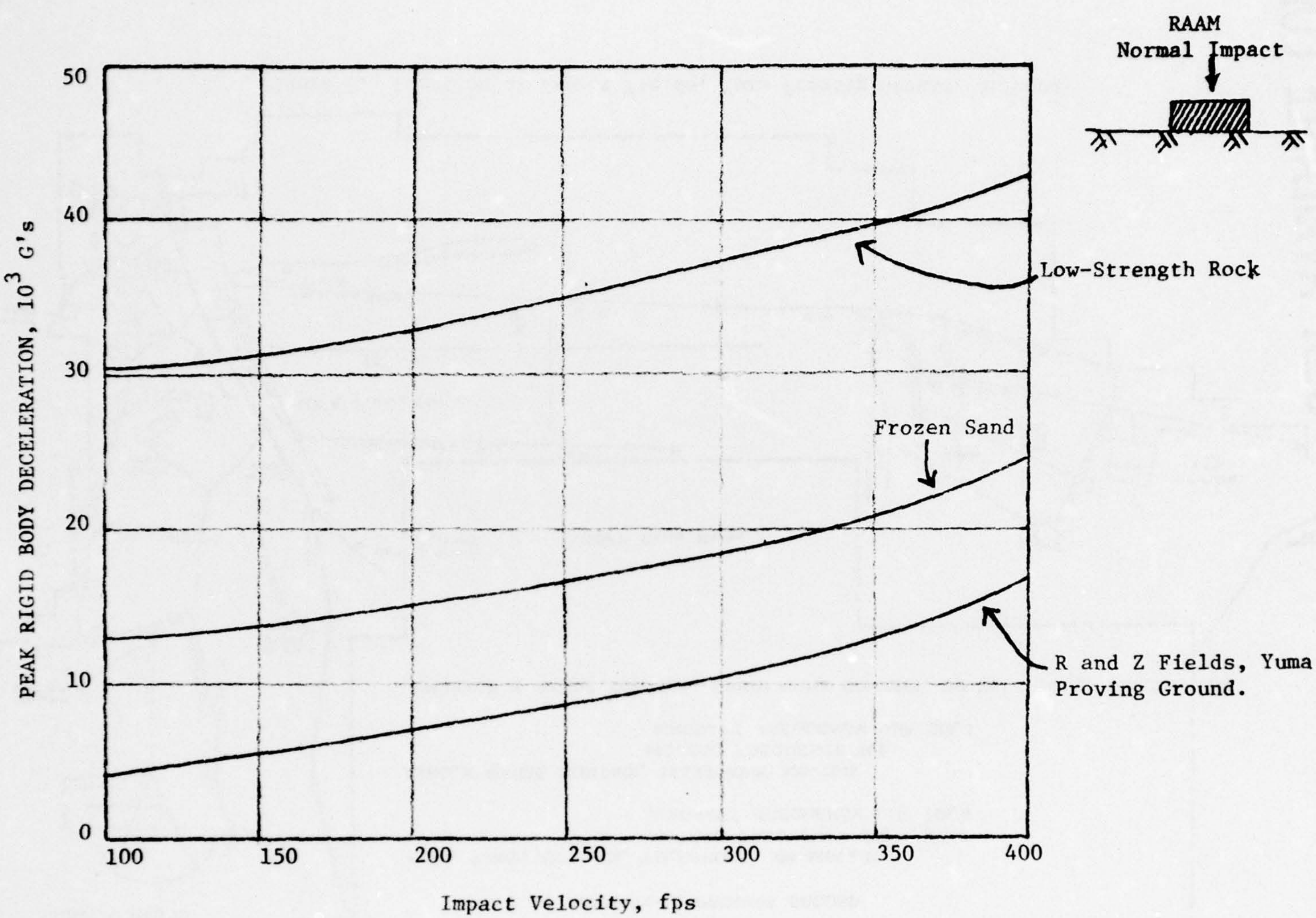

Figure 2. Calculated Peak Rigid Body Deceleration-Impact Velocity for Selected Surface Materials

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